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Size matters in insects – an introduction

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Size is an important indicator of fitness in insects. Overall, larger individuals live longer and have higher reproductive success than small individuals. Large males are better competitors for access to females and large females produce more eggs. Although the evolutionary pressures for increased body size are evident, it is less clear why not all individuals become large. Obviously, environmental factors, such as food availability, can put important constraints on the determination of size, but there are also ontogenetic differences in growth patterns that have a genetic basis. More needs to be learned about the interaction between genes and the environment during various insect developmental stages in determining adult size. This special issue features eight papers that investigate causes and consequences of fitness differences in a range of insect species with a focus on the role of body size.

Genetic variation for size development is addressed by Meister et al. (2018). They report large size differences between populations of the moth *Ematurga atomaria* (L.) (Lepidoptera: Geometridae) from Estonia, and a lowland and highland location from Georgia. Larger size is due to larger eggs and prolonged development time, and increases adult longevity and fecundity. The populations differ in growth patterns of the various developmental stages. Based on a common garden experiment, the authors suggest a strong genetic basis for these differences in development. As a test of the ‘good genes’ model of sexual selection, Suzaki et al. (2018) measure the indirect benefits to females from mating with attractive males in the bean bug *Riptortus pedestris* (Fabricius) (Hemiptera: Alydidae). They find support for this hypothesis in that the daughters of females that mated to attractive males had greater lifetime reproductive success in comparison with females mated to less attractive males. Although male attractiveness is related to body size (Suzaki et al., 2013), an effect of female body size on offspring quality was rendered unlikely.

Najafpour et al. (2018) look at the effect of maternal age and rearing condition on progeny fitness of the parasitoid *Lysiphlebus fabarum* (Marshall) (Hymenoptera: Braconidae)

on three aphid host instars. Maternal rearing condition and age are found to affect developmental time, body size, and egg load of progeny. Their results point toward maternal effects on egg size and progeny performance, which is rare in parasitoids. The effects of symbiotic bacteria on adult fitness of pea aphids, *Acyrtosiphon pisum* Harris (Hemiptera: Aphididae), are studied by McLean et al. (2018). Although female fecundity was not directly affected by the presence of facultative symbionts, females mated to cured males laid fewer eggs than females mated to males that carried *Hamiltonella defensa* Moran et al. These results remind us of the importance of the microbiome as an additional factor in determining insect fitness.

The other studies in this issue address the role of the environment in determining adult size. Shelly (2018) investigates the effects of larval diet on male body size and mating success of the melon fly, *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae). Although larval host plant can affect adult mate choice, developing on different host fruits (zucchini vs. papaya) did not result in assortative mating of adults. Instead, all females appeared to prefer males that had grown up on zucchini. The reason appears to be that males develop faster in zucchini, grow larger, and dominate male–male interactions. Hence, zucchini may be a better host for development of *Z. cucurbitae*. Rios Martinez & Costamagna (2018) investigate how crowding, host plant quality, and within-plant distribution affect morph determination in the soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae). The authors experimentally altered density levels in the field and observed strong effects on adult body size which was used as an estimate of aphid performance. As a correlative response, they found that the proportion of alate individuals increases with crowding and lower host plant quality, consistent with previous reports.

Tran et al. (2018) study the effect of nutrient enrichment on the morphology and behavior of the house cricket, *Acheta domesticus* (L.) (Orthoptera: Gryllidae). Diet-supplemented individuals had larger femurs and demonstrated increased locomotor activity and jumping distances. They grew faster as juveniles and matured earlier, but this did not affect adult body size. Interestingly, and in contrast to the often observed positive correlation

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between size and longevity, dietary restriction can also extend life span. However, it typically negatively affects reproduction. The results of this study are also relevant to humans as athletic supplements may substitute exercise for muscle development. Using *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) fruit flies, Semaniuk et al. (2018) investigate how food intake influences egg production but fail to find this predicted trade-off between life span and reproduction. Taken together, these studies find clear effects of nutrition on adult fitness, even though the specific impacts of body size on reproductive performance differ among species.

Knowledge of the genetic and environmental determinants of insect body size has clear applied relevance. Many insects are mass reared for insect pest control programs. For instance, the success of the sterile insect technique depends critically on the fitness of the released males, as these need to favorably compete with wild males (Orozco-Dávila et al., 2017; Scott et al., 2017). The articles in this current special issue on insect fitness clearly demonstrate that larger males have a competitive advantage and that adult size depends on nutritional settings, stressing the importance of optimal conditions in insect mass rearing. Female size is also known to be positively related to fecundity (Choe & Crespi, 1997). Many biological control programs use female parasitoids against insect pests. As larger females lay more eggs and parasitize more hosts, rearing conditions of these control agents need to be optimized to maximize adult size. This special issue demonstrates that pest control programs can benefit from knowing and selecting genetic and environmental factors of insect growth.

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